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INSULATORS FOR $Pb_{1-x}Sn_xTe$

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ABSTRACT

Thin films of LaF_3 have been e-gun and thermally deposited on several substrates. The e-gun deposited films are fluorine deficient, have high ionic conductivities that persist to 77°K, and high effective dielectric constants. The thermally deposited material tends to be closer to stoichiometric, and have higher effective breakdown field strengths. Thermally deposited LaF_3 films with resistivities in excess of $10^{12}\Omega$-cm were deposited on metal coated glass substrates. The LaF_3 films were shown to adhere well to PbSnTe, surviving repeated cycles between room temperature and 77°K. LaF_3 films on GaAs were also studied.

A lengthy mid-year report was submitted in which details of the sample preparation methods and some results obtained on LaF_3 insulators on PbSnTe samples and other substrates were presented. The main results were that this insulator could be made with resistivities in excess of $10^{12}\Omega$-cm and was thermally compatible with the PbSnTe material. LaF_3 coated PbSnTe samples could be cycled between room temperature and 77°K repeatedly without seperating from the substrate. These preliminary results were obtained on highly doped samples, and the goal of the second period was to make some deposits on low carrier concentration samples so their space charge and interface state characteristics could be measured.

Two PbSnTe samples designated 4TI and 5TI were prepared and tested. The sample preparation procedure that was used follows:

1) Back aluminum contacts were deposited.
2) The front surfaces were mechanically polished
3) The samples along with Cd(99.9998%) metal were sealed under vacuum in a quartz tube.
4) The tube was heated to 400°C for 120 minutes.
5) The front surfaces of the samples were then electrochemically polished.
6) LaF_3 thin films were thermally deposited.
7) **Finally, aluminum contacts were deposited.**

The first sample prepared in this fashion was 4TI. It had a 1500Å layer of LaF_3. There were two dots deposited on the front surface. One of the dots was shorted from the outset. The second was the best sample in this series. Capacitance and disapation factor measurements at 100kHz were made on it at room temperature with bias voltages ranging from -4 volts to +4 volts. Initially it exhibited no discernible leakage current. Unfortunately it broke down and shorted before it was tested at 77°K. Because at room temperature the carrier concentration was high, the 100 kHz capacitance and disapation factor were as expected essentially constant at all bias voltages.

The second sample 5TI had a 1200Å LaF_3 layer. Six dots were deposited on it. All of these dots leaked, so only zero bias measurements were made.

The sole positive result from these two samples was the demonstration that it is possible to deposit a blocking LaF_3 contact on PbSnTe. Unfortunately this experiment exhausted our supply of PbSeTe. Clearly additional work is needed to bring the LaF_3 deposition process under better control so the yield is improved.

Since we exhausted our supply of PbSnTe we carried on our studies of LaF_3 deposition methods on a few good samples of GaAs that we had. The GaAs was chosen for two reasons. It, like PbSnTe, is a material on which it is difficult to form good blocking insulator layers. The second reason is that GaAs is well known to have a large interface state density peak in the band gap that prevents it from being inverted. If GaAs could be inverted then inhancement mode MOSFET devices could be built from it with their well known advantages over the current depletion mode GaAs MESFET devices. In another study there were indications that LaF_3 on the GaAs surface reduced the troublesome interface density.

An n-type GaAs sample was coated with 1000Å of LaF_3. The upper gate electrod area was a rather large 0.11 cm^2. No attempt was made in the vacuum station to remove the thin oxide layer that is always present on GaAs. Thus the LaF_3 deposit was placed on top of this thin layer. This is a circumstance that will need to be remedied in future experiments. The vacuum used in the deposition was poor $\sim 10^{-6}$ torr. Thus some oxygen contamination is present in the LaF_3. Once again this is a feature that should be eliminated. Finally the GaAs substrate temperature was not controlled during the deposition, and this is a variable that should be optimally chosen. Thus there are significant improvements that can be made.

Despite this the LaF_3 film did not break down for gate voltages ranging between +1 and -10 volts. The leakage current density observed at +1 volt, where the sample is in accumulation so all the voltage is across the insulator, was 200 nA/cm^2 which corresponds to a resistivity of $5 \times 10^{11} \Omega$-cm. While this is a high resistivity, particularly for the size of the area being used, it is still not large enough to make standard quasistatic capacitance vs. voltage measurements easy to interpret. The

results are inconclusive, but the quasistatic capacitance showed a tendency to increase as the bias voltage was lowered. If this behavior is verified it would support the conclusion that the Fermi energy had passed over the interface state density peak and the sample was beginning to invert.

We plan one further measurement on this sample. We have access to a Solartron frequency response analyzer. This device measures the complex impedance of a circuit from 10^{-4} Hz to 10^{4} Hz. It can be used to make reliable impedance measurements at very low frequencies even in the presence of small leakage currents. A preliminary measurement on this sample displayed a totally unexpected feature. The sample evidently exhibited a multiple resonance at a few mHz. The Nyquist plot has three cycles. The preliminary measurement was made with an improper impedance matching circuit between the sample and the Solartron. The defects in the matching circuit should not have caused the resonances, but it does distort them so they aren't accurately measured. A new matching circuit is currently under construction, and when it is completed another data set will be taken and analyzed.

Finally, we conclude that it is possible to make useful insulators for electronic devices from LaF_3, however we still have not optimized the deposition processes. LaF_3 will adhere to PbSnTe and we expect it will be a useful insulator. Since PbSnTe has a high dielectric constant, insulators for it must also have high effective dielectric constants. This can be best accomplished with LaF_3 by e-gun depositing the material. E-gun deposited LaF_3 is fluorine defficient. This material has a high ionic conductivity, and thin dipole layers even at 77°K. Thus it responds as though it were a high dielectric constant media, which when made properly has a large breakdown field strength.